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Cities, Mobility and Climate Change

David Banister

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Cities, Mobility and Climate Change

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1. Introduction

There are enormous benefits from travel, as economies have become more globalised and as the new communications infrastructure allows international networking at low cost. People's aspirations and expectations have been increased through media coverage of world events, through more educational and leisure opportunities, and through increasing wealth. There is a true internationalisation of all activities, and travel forms an essential part of that process. To counter that optimism is the evidence that we now live in the carbon society, and that carbon emissions are affecting the global climate with irreversible long term consequences. Transport is the one sector where such a reduction in energy use and emissions is proving to be extraordinarily difficult to achieve.

In urban areas, there are many good examples of reductions in energy use in transport, principally through demand management (pricing, parking and access control, congestion charging), investment in public transport, priority for walking and cycling, and a range of soft measures designed primarily to reduce the use of single occupancy cars. In addition planners have been active in creating high quality local neighbourhoods, including innovative designs for housing and mixed use developments, and the concentration of development around public transport accessible locations. In all cases, the intention is to reduce the need to travel (particularly by car), to encourage greater use of public transport (and walking and cycling), and to reduce travel distances. The key here is to provide quality, with easy access to local services and facilities, so that people do not need to travel long distances. There are positive signs that city living is becoming "fashionable" and that sustainable lifestyles are being adopted by many people (Banister, 2005).

This paper presents a global picture of what is happening in terms of cities, mobility and climate change, highlighting recent trends. It is argued that the current situation is unsustainable, and that transport must contribute fully to achieving carbon reduction targets. A proposed alternative is presented, based on the sustainable mobility paradigm (Banister, 2008) that looks at ways to reduce the need to travel in cities. The belief that technology provides the solution is misplaced, as technological innovation can only get us part of the way to sustainable transport. Finally, it is suggested that there may be opportunities for cities in the developing world to switch to low carbon systems without passing through the period of oil dependency. Potentially, the future is bright for low carbon transport in cities, but the real question is whether there is the commitment and leadership to follow such a path.

2. The Reality in the EU

In most EU cities, there are some indications that modest change in behaviour has taken place. The real challenge is not the acceptance of the strong links between mobility and climate change, but the imperative for substantial behavioural change. The scale of the problem has been totally underestimated,

Table 1: EU27 energy consumption and GHG emissions in transport and growth in travel (1990-2005 - Data indexed to 1995 = 100)

EU27	Total energy consumption in transport (mtoe)			GHG emissions from transport activities ($mtCO_2e$)			Travel by car (m pass km)			All passenger travel (m pass km)	
	1990	2000	2005	1990	2000	2005	1990	2000	2005	2000	2005
	93	113	121	93	113	123	88	111	117	111	118

Notes: 1. Total energy – all modes, including rail, road, air and inland navigation

2. Aggregate emissions of Kyoto basket of 6 GHG weighted by their global warming potentials.

and the actions being taken by governments at all levels are not addressing the seriousness of the issues. Even the actions taken by the most environmentally aware individuals are not sufficient, as it has proved very difficult to stabilise the level of carbon emissions from transport, let alone reduce them (Table 1). Since 1990, there has been a steady increase in energy, emissions and travel in the EU27, and the pattern seems to suggest that the increase in energy and emissions is growing at a faster rate over this period than travel.

Even though schemes have been implemented to reduce the use of the car in cities and to make its use more efficient elsewhere, there has still been a substantial growth in travel distance, as cities have spread and as the desire for low density car based lifestyles has become dominant. The technology has not kept pace with the growth in car based travel, and even a substantial shift to more efficient vehicles and alternative fuels will not address the problems fully. Over the next 25 years, it has been estimated that the maximum (possible) contribution of technological innovation to reducing CO_2 emissions in the transport sector in the UK would be about 21MtC (to 2030) (Banister and Hickman, 2006). This is about half the levels required to achieve a 60% reduction, equivalent to the targets set by the IPCC over the longer period to 2050[1] (IPCC, 2001 and 2007).

Such a change would require the "average" cars to have a CO_2 emissions profile of 90 g/km, which is less than the current benchmark level of 104 g/km (Toyota Prius and Citroen C1), with half the fuel that is still needed by these vehicles being sourced from second generation biofuels. The current average level of emissions of new cars in the UK (2005) is 169 CO_2 g/km (SMMT, 2006). Similar changes would be required in all EU countries. Massive investment would be required in changing production processes for the new super efficient cars, in sourcing substantial quantities of alternative fuels, and in giving incentives to industry and individuals to use these new vehicles. Perhaps the only way to achieve such a change would be to switch to electric city vehicles, but even here there would need to be a new support infrastructure, and the power would have to be generated from renewable sources.

Significant reductions of CO_2 emissions in transport in the EU can only be achieved through behavioural change. There is little sign that people are aware of the scale of the challenge, or prepared to make the necessary changes. Globally, carbon emissions per capita are about 4.37 tCO_2 (2006) (1.07 tCO_2[2]), but the EU27 average is about 9.28 tCO_2 (2.53 tCO_2) and the US figure is 19.45 tCO_2 (6.80 tCO_2). The stabilisation targets mean that the average per capita level should be under $2tCO_2$ (2050) (0.75 tCO_2), much less than

[1] Note that the 60% reduction figure is that required by the IPCC to achieve the stabilisation of carbon emissions by 2050, but brought forward to 2030 (IPCC, 2007 and Stern, 2006). The UK government has set itself an 80% reduction target by 2050, so this figure is consistent (Committee on Climate Change, 2008). It also assumes that transport should take a "fair" share of the target reductions.

[2] The figures in brackets give the estimated levels of carbon dioxide emissions from the transport sector.

the current EU or US levels. It is also lower than the current level of 4.07tCO_2 for China (0.45 tCO_2) and about double the current level of 1.07 tCO_2 in India (0.10 tCO_2). This means that those countries producing more than the average levels of carbon emissions should be making an even greater contribution to the overall reduction target. The EU and the US should be leading the move towards contraction and convergence on this "stabilisation" target (Meyer, 2001). Transport can and should play a major part in achieving the target.

3. The Global Perspective

In addition to the denial of the scale of change required, there are other major difficulties in achieving sustainable transport. The US produces over 21% (2006) of the carbon emissions from energy (including transport), yet it is not part of any international agreement to reduce its emissions (EC DG Energy and Transport, 2008). Over the last ten years it has increased its CO_2 emissions by 14%, with global levels of CO_2 increasing by 24% (1995-2005). Although only 5% of the world's population live in the US, it has 30% of the cars and produces 45% of global car based CO_2 emissions (DeCicco and Fung, 2006). It is crucially important that the US is fully engaged in all international debates about reducing levels of carbon emissions, and this is at last taking place with the new President. But even here, the future still seems to be based on technological options, with tax incentives being given to promote renewable energy and biofuels. It is only very recently that the US motor industry seems to have become more aware of the need to produce a range of fuel efficient vehicles.

At the city level, there is considerable variation between cities. For example, more than half the total energy consumption in Mexico City, Hong Kong and Cape Town is transport based (UN Habitat, 2008), whilst the levels in many European cities (for example, London and Paris) is about a quarter. This reflects the different strategies adopted by city planners, such as promoting the use of the car through investment in roads and free parking, to demand management and constraints on the use of the car, and investment in local facilities and in public transport.

The politics are much wider than just the transport elements, as there are substantial income differences within and between cities, and not all people have access to transport. The UN Habitat (2008) review of world cities placed Beijing as being the most equal city in Asia (Gini coefficient[3] 0.22), but Hong Kong (also in China) has a much higher level of inequality (Gini coefficient 0.53). Recent analyses suggest that India is undergoing an inequality trend somewhat similar to that of China as a result of liberalisation and globalisation. In 2002, the income gain in the richest 10 per cent of the population was about 4 times higher than the gain of the poorest 10 per cent (UN Habitat, 2008). Investment in most transport infrastructure and services benefits the rich and not the poor.

4. Mega-Cities and Sustainable Transport

The future must be based on urban living, as over 50% of the world's population are now classified as urban dwellers (2005). There is a clear expectation that this figure will increase to 70% by 2050. These levels of urbanisation are already apparent in Europe, North America and Latin America (UN Habitat, 2008). Globally, the rate of urbanisation is now 3 million per week (UN Habitat, 2008). Mega-cities (population over 10 million) are all characterised by high population growth, both from natural increase and through inward migration, and a huge expansion in the urban area with substantial new

[3] The Gini coefficient is the most widely used measure to determine the extent to which the distribution of income or consumption among individuals or households deviates from a perfectly equal distribution. A Gini coefficient of 0 indicates perfect equality and a Gini coefficient of 1 indicates perfect inequality.

http://www.scribd.com/doc/328232/United-Nations-Gini-Coefficient requirements for both housing and jobs. The rate of increase in the supply of new infrastructure will never match the growth in demand.

These cities have tremendous potential for growth and will be the powerhouses of the world economy over the next decades, but they are also centres for potential unrest, as there is substantial inequality and poverty (UN Habitat, 2008). The challenges for governments are daunting with little space for expansion in the original cities, so there is extensive urban sprawl with increased distances between where the people live, their jobs and other facilities. The concept of single centred cities is becoming less relevant with the growth in mega-cities, as they are rapidly developing as polycentric urban agglomerations, often absorbing other smaller cities in the process.

There is a fundamental difference between the priorities in high income cities, where the main concerns are over levels of pollution and consumption related burdens, and those in low income cities, where the concerns are more short term and health related. Their requirements include clean water, waste management and sanitation. It is both the cities in the high income and the low income countries that contribute to global emissions, yet the drive for economic growth seems to be overwhelming, and it is often at the expense of other priorities, and the net effect is a continuing growth in local emissions (NO_x, CO, HC, SO_2, PM_{10}, and PM_5) and global emissions (CO_2). The high income cities have the opportunity to substantially reduce emissions through investment in clean technology and much greater energy efficiency, including a switch to low carbon energy. For the low income cities, the challenges are even greater, as they have other pressing social needs to address, but even here there are opportunities to switch to efficient low carbon energy sources.

There are good examples where development has been seen as investment, with the basic infrastructure being provided as part of the urbanisation process, as in Guangzhou City (Pearl River). Conversely, higher densities can be achieved through compactness and integrated approaches that combine investment in high capacity public transport and development, as in Hong Kong or Singapore (around their metro systems) or in Curitiba (around its bus rapid transit system). There needs to be strong city level governance, where there is a clear vision about the future of the city, and where there is both the power and resources for action. But above all, there is a need for leadership and for all stakeholders to engage with the process of city-building, so that responsibilities and actions are both supported and implemented effectively. This is the only way to move towards the sustainable city. The alternative is one of weak governance, where there is no direction and the consequences are huge sprawling divided cities – this is the inefficiency and unsustainable city.

In Europe, there are no mega-cities, the possible exception being London, where the city region has a population of 15 million (25% of national population) and 40% of the GDP. The key concerns here are quality and sustainability that cover equality of opportunity, and access to services and facilities, as well as high environmental standards. Here, the growth rates are much lower and there are strong governance structures that encourage order, priority for people, polycentric urban form (London is a city of villages), and the full integration of land use and transport.

Many of the World's great cities are located on the coast or along the major rivers, as historically they have been centres of trade. But these locations are now prone to flooding, caused by storm surges and high winds, and accentuated by global warming (+2^{o}C) and sea level rise. About 40% of the World's cities (1-10 million) and 15 of the 20 mega-cities lie on the coast. Their vulnerability to flooding has been substantially increased, and some have taken action to reduce the potential impacts, but 40 million or 10% of the total population are exposed to a 1 in 100 year coastal flood event, and this will rise to 150 million in 2070 (Nicholls et al., 2008). It is proposed that apart from upgrading protection and infrastructure to handle such events, land use planning should be used

Table 2: Contrasting Approaches to Transport Planning

The Conventional Approach **Transport Planning and Engineering**	**An Alternative Approach** **Sustainable Mobility**
Physical dimensions Mobility Traffic focus, particularly on the car	Social dimensions Accessibility People focus, either in (or on) a vehicle or on foot
Large in scale Street as a road Motorised transport	Local in scale Street as a space All modes of transport often in a hierarchy with pedestrian and cyclist at the top and car users at the bottom
Forecasting traffic Modelling approaches Economic evaluation	Visioning on cities Scenario development and modelling Multicriteria analysis to take account of environmental and social concerns
Travel as a derived demand Demand based Speeding up traffic Travel time minimisation Segregation of people and traffic	Travel as a valued activity as well as a derived demand Management based Slowing movement down Reasonable travel times and travel time reliability Integration of people and traffic

Source: Adapted from Marshall (2001), Table 9.2.

to reduce vulnerability for new developments and selective relocation of existing city areas should be considered. For example, London's flood barrier was built (1974-1983) at a cost of (£1300m in 2001 prices: $2000m) to prevent flooding from high tides and sea surges for the "100 year event". Between 1986 and 1996, the barrier was raised 27 times, but in the period 1996-2006 it was raised 66 times. The expected property damage being estimated at £30 billion ($50 billion) should it be breached, and these financial costs do not include loss of life, health and income effects.

5. The Sustainable Mobility Paradigm

Sustainable mobility provides a new paradigm within which to investigate the complexity of cities, and to strengthen the links between land use and transport. The city is the most sustainable urban form and it has to provide the location where most (70-80%) of the world's population will live. Empirical research in developed cities has concluded that the key parameters of a sustainable city are that they should be over 50,000 population, with medium densities (over 40 persons per hectare), with mixed use developments, and preference given to developments in public transport accessible corridors and near to highly public transport accessible interchanges where densities would be substantially higher (over 80 persons per hectare) (Banister, 2005). Such developments conform to the requirements of service and information based economies, and settlements of this scale would also be linked together to form agglomerations of polycentric cities, with clear hierarchies that would allow a close proximity of everyday facilities and high levels of accessibility to higher order activities (Hall and Pain, 2006).

Such urban forms would keep average trip lengths to below the thresholds required for maximum use of cycle and walk modes. It would also permit high levels of innovative services and public transport priority, so that the need to use the car would be minimised. Through the combination of clear planning strategies, cities would be designed at the personal scale to allow both high quality accessibility and a high quality environment. The intention is not to prohibit the use of the car as this would be both difficult to achieve and it would be seen as being against the notions of freedom and choice. The intention is to design cities of such quality and at a suitable scale that people would not need to have a car.

This alternative approach requires clear and innovative thinking about city futures in terms of the reality (what is already there) and the desirability (what we would like to see), and the role that transport can (and should) play in achieving these objectives. The sustainable city must balance the requirements along the physical dimensions (urban form and traffic) against those concerning the social dimensions (people and proximity), as illustrated in Table 2.

The sustainable mobility approach requires actions to reduce the need to travel (less trips), to encourage modal shift, to reduce trip lengths and to encourage greater efficiency in the transport system. To achieve a sustainable transport system, we must travel less.

5.1 Reducing the need to travel - substitution

In its pure form this means that a trip is no longer made, as it has either been replaced by a non-travel activity or it has been substituted through technology, for example Internet shopping. The impact of information and communications technologies (ICT) on transport is complex, and current thinking (Banister and Stead, 2004) argues for complementarity between transport and ICT. Although there is a large substitution potential, the relationships between transport and ICT seem to be symbiotic with a greater opportunity for flexibility in travel patterns, as some activities are substituted, whilst others are generated, and some replaced by fewer longer distance journeys (Lyons and Kenyon, 2003). There is also the possibility of carrying out a "trip tour", where several activities are engaged in so that one longer journey replaces three or four shorter single activity trips. There is a net saving in travel distance. Technology facilitates many different combinations of activities.

5.2 Transport policy measures - modal shift

Transport policy measures can reduce levels of car use through the promotion of walk and cycle and the development of the new transport hierarchy (Table 2). This can be achieved through slowing down urban traffic and reallocating space to public transport, through parking controls and road pricing, and through making it easier to use public transport. Demand management is effective in restricting access and reallocating space, and making more effective use of the available capacity. A much wider notion of the street is being created, as it is no longer only being considered as a road but also as a space for people, green modes and public transport. Creative use of that space at different times of the day or day of the week means also that new uses can be encouraged (e.g. street markets or play zones). Measures to encourage modal shift must be combined with strategies to make the best use of the "released space", so that there is a net reduction in traffic (Banister and Marshall, 2000).

5.3 Land use planning measures – distance reduction

These measures address the physical separation of activities and the means by which distance can be reduced. The intention is to build sustainable mobility into the patterns of urban form and layouts, which in turn may lead to a switch to green modes of transport. It is one area of public policy were intervention can take place, through increasing densities and concentration, through mixed use development, through housing location, through the design of buildings, space and route layouts, through public transport oriented development and transport development areas, through car-free development, and through establishing size thresholds for the availability of services and facilities (Section 6). The timescale over which sustainable mobility might be realised is similar to the turnover of the building stock (about 2 per cent per annum), but decisions on the location of new housing will have a single dramatic effect on travel patterns and these effects will impact over the lifetime of that housing.

5.4 Technological innovation – efficiency increase

The role of technology is still important, as it impacts on the efficiency of transport directly through ensuring that the best available technology is being used in terms of engine design, alternative fuels, and the use of renewable energy sources. Standards can also be introduced to reduce levels of noise and emissions at source, and measures can be taken to ensure that access to certain parts of the city are restricted to those vehicles that are seen to be environmentally cleaner than other vehicles. This is a combination of technological efficiency and behavioural change (e.g. ecological driving and adherence to speed limits). It would also include increasing load factors in both the passenger and freight sectors, where again there are substantial opportunities to use the new technologies creatively to match up journeys or loads to increase occupancy levels.

Summarising these four actions, it seems that the key to such a shift in thinking is the creation of spaces and localities in the city that are attractive and affordable, as neighbourhood quality is central to sustainable mobility. Transport planning must involve the people[4], so that there is an understanding of the rationale behind the policy changes and an increased likelihood that behavioural change follows. Public acceptability is central to successful implementation of radical change, and it must involve community and stakeholder commitment to the process of discussion, decision making and implementation.

6. Planning for City Futures

Trying to unravel the complexities of the interrelationships between travel, urban form and sustainable development is difficult. Underlying the discussion is the requirement to have some vision of the city in its desired form – it should be viable (economic justification), have vitality (inclusive and fair), and it should be healthy (high quality of life and environmental quality). Transport provides an essential element in city viability, vitality and health. The EU vision is based on maintaining the quality of urban life, urban planning and sustainable development, where mixed uses, high densities and good environmental conditions are seen as being central to both improving economic performance and the vitality of cities.

This vision has resulted from the assessment of the substantial research that has tried to establish the links between travel, land use and urban form. This research ranges from simple analyses of trip generation and attraction characteristics of particular land uses (e.g. residential and shopping) to more detailed analyses of travel (and energy use) in locations with distinctly different characteristics. The verdict on this empirical work is mixed. For example, Anderson et al (1996) concluded that the current level of understanding of the influence of urban form on the generation of emissions and the use of energy is weak. But others (e.g. Stead, 2001 and Hickman, 2007) have found far more significant relationships between land use and transport. In both these cases, the socio economic variables explain substantially more of the variation in trip making activities than the land use factors. Underlying all the debates, three main elements need to be examined:

6.1 Density of development

Density of development has an important effect on the distances travelled, the modes used and the energy profiles. The most cited research here has been carried out over the last 15 years by Newman and Kenworthy (1989a and b, 1999) in their comparison of the transport energy profiles of 84 cities. Their powerful conclusion was that when urban density in the 58 wealthier cities was correlated with car passenger kms, urban density explained 84% of the variance (Kenworthy and Laube, 2001; Kenworthy, 2007). When energy use was correlated with activity intensity (persons and jobs per hectare), 77% of the variance was explained. Despite concerns over the methods used and the quality of the data, clear relationships have been established at the city level. A general conclusion is that an increase of 10% in local density results in a 0.5% decrease in vehicle trips and vehicle miles

[4] People are used here to cover all stakeholders with an interest in the quality of their local environment.

travelled (Ewing and Cervero, 2002; Table 5).

In Hong Kong, the role of land use in mode choice is clear due to the densely built environment. Empirical modelling confirmed that the role of land use in influencing travel was independent from travel time and monetary costs. Elasticity estimates show that the composite effect of land use on driving could be comparable in magnitude to that of driving cost. Land use strategies influence travel more effectively when complemented by pricing policies (Zhang, 2004).

Settlement size is also important in influencing both modal shares and the distance travelled as use of public transport and walking increases with population size (Dargay and Hanly, 2004). Diseconomies of scale may feed in with the largest cities, which have a complexity of movement that is substantially greater than the smaller monocentric cities – circumferential trips are as important as radial trips (Banister, 1997).

The US literature is also variable in its findings, as Ewing (1997) estimated that a doubling of density resulted in a 25-30% lower level of vehicle miles travelled (VMT), whilst Holtzclaw (1994) concluded that the difference between 20 dwellings/acre (urban densities) and 5 dwellings/acre (suburban densities) was a 40% increase in travel. Overall, the US evidence seems empirically powerful, suggesting that higher density developments can reduce VMT by at least 10-20% as compared with urban sprawl (Litman, 2007; Table 6).

6.2 Proximity and Quality

Land use patterns in post industrial cities are changing as greater mixed use becomes the dominant feature. This means that journey lengths can be reduced through the use of local facilities and services. Considerable effort is now being placed in transport development areas (or the similar transit oriented developments in the US), where high quality public transport accessibility can be combined with office development, residential, leisure and retail activities, all in close proximity to each other. The importance of quality is paramount, as these accessible locations become the centre of activity and increasing the demand for public transport. This is a concentration of activity that has beneficial impacts on modal split and the use of local facilities, but it needs to be balanced against the counter trend of dispersal (and sprawl) that has an opposite effect on trip lengths and greater levels of car dependence.

Cervero and Duncan (2006) examined the degree to which job accessibility is associated with reduced work travel and how closely retail and service accessibility is correlated with miles and hours logged getting to shopping destinations. Based on data from the San Francisco Bay Area, they found that jobs-housing balance reduces travel more, by a substantial margin, than accessibility to shopping. But they also concluded that it is important to look at access to public transport at both ends of the journey. By concentrating "housing near rail stops will do little to lure commuters to trains and buses unless the other end of the trip – the workplace – is similarly convenient to and conducive to using transit." (Cervero, 2006, p53).

6.3 Local Neighbourhood and Design

The new urbanism debate encourages more local activity through more walking, direct routing for slow modes of transport, and quieter and narrower streets (Duany and Plater-Zyberk, 1991, Calthorpe, 1993, Marshall, 2005 and 2008). People travel shorter distances when they move into neighbourhoods with higher accessibility (Krizek, 2003), with median distance increasing from 3.2km in the more accessible neighbourhoods to 8.1km in less accessible neighbourhoods. Street connectivity is also important here as it can reduce distances for slow modes, but cul de sacs are also popular with residents, even though they tend to extend travel distances. Main Street programmes in the US (and more recently in the UK) are intended to revitalise town centres by restricting access at certain times and to create vibrant communities day and night (Handy, 2004). Other initiatives to encourage urban living include extensive pedestrianisation, the

Table 3: GHG Emissions for Different Housing Types in Toronto

Annual GHG Emissions kg CO^2eq/person/year in 1996	Suburban Detached		Urban Apartments	
		%		%
Construction	597	7	391	12
Building operations	2730	32	1510	45
Car travel	5180	60	1420	43
Bus transport	130	1	20	-

Based on Table 4 in Norman et al. (2006)

closure of residential streets, gated communities, and even the removal of freeways (e.g. the Embarcadero Freeway in San Francisco). The issue of parking management is central here.

One of the few detailed empirical studies has been carried out in Toronto (Norman et al., 2006) for city centre apartments (net residential density 150 dwellings/hectare) and suburban detached housing (net residential density 19 dwellings/hectare). Although the GHG emissions and energy density were similar per unit of living space (m^2) for construction materials, building operations and transport, the figures per person are very different (Table 3). This is due to the additional space available per person in the suburban detached housing. The GHG emissions are 2.5 times higher in the suburban than the urban housing. For transport, the figures are stark, with GHG emissions (and energy use) being more than 3.5 times as high in the low density housing for car and 6.5 times as great for public transport.

A large sample of the Great Britain National Travel survey was taken by Dargay and Hanly (2004) for 1989-1991 and for 1999-2001 to test for the impact of land use characteristics on the level of mobility and the use of cars. They concluded that land use characteristics (population density, settlement size, local access to shopping and other facilities and accessibility of public transport) play a significant role on car ownership and use of the car. Density has a greater impact than settlement size, and proximity to local facilities encourages walking instead of car travel.

6.4 Cumulative Effects

Land use effects on travel behaviour tend to be cumulative and mutually reinforcing (Hickman, 2007; Litman, 2007). This effect can be illustrated in two ways. Ewing and Cervero (2002) calculated the elasticity of vehicle trips and travel per capita with respect to four land use variables (Table 4). Their estimates suggest that a doubling on local density reduces car trips by 5% per capita and travel by about the same amount. Although the elasticities are low, Ewing and Cervero (2002) concluded that they were cumulative, giving a total potential of 13% and 33% decreases in trips and trip distance (VMT) respectively.

The second study was by Lawton (2001) using data from Portland Oregon to examine the impact of land use density, mix, and road network connectivity on personal travel. As urbanisation increases, per capita vehicle travel declines significantly from about 20 average daily travel miles per adult (32kms) to just over 6 miles (10kms).

Table 4: Elasticities of Trips and Travel by Land use Factors

Factor	Description	Trips	Travel (VMT)
Local density	Residents and employees divided by land area	-0.05	-0.05
Local diversity	Jobs/residential population	-0.03	-0.05
Local design	Sidewalk completeness/route directness and street network density	-0.05	-0.03
Regional accessibility	Distance to other activity centres in the region	-	-0.20

Source: Ewing and Cervero (2002)

The main conclusions with respect to the impacts of the land use factors on travel distance are (Banister and Hickman, 2006) are sixfold: At the regional level, the location of new development, particularly housing, should be of a substantial size and located near to or within existing settlements so that the total population is at least 25,000 and probably nearer to 50,000. The provision of local facilities and services should be phased so as to encourage the development of local travel patterns. Secondly, density is important and average journey lengths by car are relatively constant (around 12km) at densities over 15 persons per hectare, but at lower densities car journey lengths increase by up to 35%. Similarly, as density increases, the number of trips by car decreases from 72% of all journeys to 51%. Car use in the high density locations is half that in the lowest density locations. Thirdly, mixed use developments should reduce trip lengths and car dependence. Although research here is limited and concentrates on the work journey, there is considerable potential for enhancing the proximity of housing to all types of facilities and services. Fourthly, as settlement size increases, the trips become shorter and the proportion of trips by public transport increases. Diseconomies of size appear for the largest conurbations as trip lengths increase to accommodate the complex structures of these cities. Fifthly, development should be located near to public transport interchanges and corridors so that high levels of accessibility for all can be provided. But this may also encourage long distance public transport commuting. Free flowing strategic highway networks are likely to encourage the dispersal and sprawl of development and stretch commuting. Finally, the availability of parking is a key determinant of whether a car is used or not and appropriate standards need to be linked to accessibility levels.

These points are well summarised (Table 5) by Litman (2007), who concludes that in the US a 10-20% cumulative total saving in VMT is possible through density and mixed design, and a further 20-40% is possible form regional decisions on the location of new development. The figures in the UK are likely to be less, as the trip distances travelled are lower and there is already a much greater use of land use and development controls than in the US.

The McKinsey report (December, 2007) set a carbon abatement cost at $50 per tonne CO_2e, and concluded that the US can reduce their emissions by between 3.0 and 4.5 Gt CO_2e by 2030 (31% to 49% reduction). About a third of this figure would come from action on the built environment (buildings) and transport, but it was assumed (p42) that there was no change in consumer utility. Urban design and denser, more transport efficient, communities were not assessed. It was also expected that there would be significant increases in distances travelled in the US over the period 2005-2030. The evidence cited here suggest that behavioural change and land use and development decisions can all have a substantial influence on travel and energy use, and must contribute to substantial reductions in CO_2 emissions.

Although the empirical evidence may be limited, there is considerable potential for reducing the energy (carbon) use in transport in cities, through creative planning of new developments and the regeneration of existing areas. It is through higher densities (40 persons per hectare minimum and 80 persons per hectare desirable), high quality local environments, with close proximity to work and a range of services and facilities, in neighbourhoods that provide safety and security, so that the city can operate 24/7.

Transport is designed out of much of the city, and where it is needed, priority is given to high quality public transport and cycling and walk. The role of the car in the city may be limited to ultra clean electric or plug-in hybrid vehicles powered by renewable energy.

Table 5: Land Use Impacts on Transport – US Evidence

Factor	Definition	Travel Impacts
1. Regional Accessibility	Location of development relative to regional urban centres	Improved accessibility reduces per capita vehicle mileage. Residents of more central neighbourhoods typically drive 10-30% fewer miles than urban fringe residents.
2. Density	People or jobs per unit of land area	Increased density tends to reduce per capita vehicle travel. Each 10% increase in urban densities typically reduces per capita VMT by 1-3%.
3. Mix	Degree that related land uses are located close together	Increased land use mix tends to reduce per capita vehicle travel and increase the use of alternative modes, particularly walking. Neighbourhoods with good land use mix typically have 5-15% lower vehicle miles.
4. Public Transport Accessibility, Walking and Cycling Conditions	Quality of public transport and degree to which destinations are accessible; Quantity, quality and security of walking and cycling	Residents with good access to public transport tend to own 10-30% less cars, drive 10-30% fewer miles, and use alternative modes 2-10 times more frequently than residents in car oriented developments. Residents in more walkable communities walk 2-4 times as much and drive 5-15% less than if they lived in more car oriented developments.
5. Centredness, Network Connectivity, Design and Management of Routes	Location of employment in major activity centres, connectivity of the network (including density), design and layout of streets	Typically 30-60% of commuters to major commercial centres use alternative modes, compared with 5-15% of commuters at dispersed locations. Better road connectivity can reduce vehicle mileage and better cycling and walking provision also helps these modes. More multi modal streets improves use of alternative modes, with traffic calming reducing car use and increasing walking and cycling.
6. Parking Supply and Management and Site Design	Number of spaces per unit area, costs, time limits and management, and layout considerations	Parking management strategies can significantly reduce car ownership and mileage. Cost recovery pricing reduces car trips by 10-30%. Mobility management can also reduce car trips by 10-30%.

7. Conclusions and Implications for Cities in Developing Countries

Cities in developing countries are following the same path, with the affluent middle classes buying cars as soon as they can and with all people then having to live with the consequences for congestion, safety and the quality of the environment. The more efficient public transport, motorbikes and bicycles are squeezed out to make way for the car. The car then dominates much of the available urban space and this has consequences for all other activities. An opportunity has been missed, as it suggests that the car dominated US city is the only future. The EU cities offer a different perspective, as much of the existing urban structure has been maintained and there has been considerable investment in public transport. However, there is still the problem of urban sprawl where both the land use and travel patterns are based on car dependent lifestyles (Banister, 2006).

Cities that currently have low levels of motorisation are changing out of all recognition. About half of the world's population now live in urban areas, and this is increasing as migration takes place and as more city jobs are created. The inherent flexibility in the use of street space for markets, small industrial activities and social spaces is being replaced by traffic, so that the car can dominate. The car based mobility requires mass redevelopment of the city or expansion so that the necessary capacity can be created. Such "solutions" are costly and have substantial implications for social welfare, environmental quality and health. The new mega cities of the world are emerging, not as the models of sustainable development, but as replicas of the car dependent cities of the West.

Apart from the lack of a clear vision and the seductiveness of following the high mobility option, there are two other key observations. One is that this option is extremely inequitable, as it favours the rich that can afford the new mobility, and it creates even greater problems of mobility for other people. This is the classic situation where individual welfare is a much stronger force than societal welfare. The second is that to create change, there needs to be an alternative that is strongly supported by both the politicians and the public. Leadership and strong governance structures are essential, so that longer term priorities are matched up with short term gains, and that investment and positive actions taken consistently over time. Unfortunately, these key elements are often lacking in most cities.

This is the basic dilemma facing cities in terms of mobility and climate change. We all like travelling and we are doing much more of it. Yet we are also aware of the environmental costs of travelling and our responsibilities both locally and globally. Our social networks are increasingly international and the global economy is also dependent on long supply chains. To some extent individual behaviour can be modified and we can substitute travel with technological communication. But in many cases there is no substitute for face to face communication, and we want to see the world. It presents a classic case of the conflict between individual preferences and choices, as opposed to the wider needs of society to protect the environment and future generations.

At present the scale and nature of the changes necessary in the transport sector to address climate change have not been seriously debated. Pricing for the external costs of transport would help, as would regulations on emissions and heavy investment in clean technology. But even here, the price rises necessary to create real change are not politically acceptable, as both industry and the electorate are powerful pro car lobbies. The real challenge confronting society is greater than this, namely the expected growth in travel from all cities and the desire for longer distance travel. Serious debate and action on these issues has not even started, and all the time the climate change clock is ticking.

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